ABSTRACT

Accidents associated with industrial activities are posing a major threat across the globe on account of the rapid industrialization and complexity of industrial units. Storage and handling of enormous quantities of hazardous substances in industrial sectors pose major threats to public health and safety. The main types of accidents that may occur in chemical process industries are fire, explosion or toxic release. The chlor-alkali sector is the most intensive area among the companies in this field. Safety aspects are of very much concern in these sectors due to the potentially serious hazards that are connected with production and storage of chlorine and hydrogen. An accidental release of chlorine can lead to devastation of large magnitude since chlorine cloud can spread extensively. It has the potential to cause death and severe injuries to people. Failure of hydrogen storage facility can also cause a series of accidents, such as jet fire, flash fire or vapour cloud explosions. A number of such accidents have occurred in the past and are still occurring in the industrial sectors. In such circumstances, the only Process Safety and Risk Management (PSRM) studies, pertaining to each facility in the industry, can reveal the most likely modes of breakdown and the relevant safety measures to control the same. Against this background, research activities are being actively pursued to offer solutions for facilitating the chlor-alkali industries situated in the countries to function effectively.

PSRM in chemical process industries is selected as the broad area of this research. The major elements of the PSRM include hazard identification, consequence assessment, probability of accidents, mitigation of consequence and emergency response planning. A chlor-alkali industry situated in south India was chosen for this research. The hazards associated

with facilities and the possible accident scenarios in the chlor-alkali industry have been identified. The chlorine storage and hydrogen holder facilities were identified as major hazardous areas associated with the chlor-alkali industry under consideration.

The consequence assessment of the worst case scenarios of chlorine release from the storage tank was conducted and its effect zones were determined. Calculations were used to determine the discharge rate of chlorine in different phases. Dispersion calculations were used to determine the chlorine concentrations at different locations from the release point. People inhabiting a radial distance of 9 km in the direction of wind are more likely to be exposed to a concentration of 3.7 ppm. The probit analysis was used to estimate fatalities for the various accident scenarios. It is estimated that about 18000 people will be affected by this incident.

The consequence assessment of Vapour Cloud Explosion (VCE) following catastrophic failure of hydrogen holder was conducted and its effect zones were determined. The equivalent TNT mass model, TNO multi energy model and Baker-Strehlow models were used to calculate the overpressure from the explosion. An overpressure value ranging from 0.05 bar to 5.5 bar was estimated at a different distance from centre of explosion. The probit analysis was used to estimate the fatalities at the accident scenario. It is identified that the operator’s cabin of hydrochloric acid plant is situated well within the blast radius of 12 m from the centre of explosion and it is recommended that the cabin be shifted to a safer location. The recommendations of measures to improve the safety of hydrogen holder were presented.

The failure probabilities of chlorine storage, tonner filling and truck container loading facility were calculated. Fault Tree Analysis (FTA) of chlorine storage, tonner filling and truck container loading facility was described. According to failure modes of storage facility, thirty one basic events were considered for FTA. Expert elicitation and fuzzy set theory were used to get the failure probabilities of the basic event in this research. The estimated failure value of basic events was compared with that of the Indian and international level researches conducted in different parts of the world. The results show that the failure probability values estimated using fuzzy fault tree analysis were found to be higher than those obtained from the internationally published data. This calls for a better focus on emergency preparedness and disaster mitigation in Indian chlor-alkali industries.

A new mitigation model for the effects of liquid chlorine release from the storage facility was proposed. A provision to recover the leaked chlorine was also proposed in the mitigation system. During chlorine release, the mitigating system starts operating automatically with different response time. The details of items required for the proposed mitigation model were presented. The estimation of cost associated with the proposed modification was also done based on the local prevailing market rate for labour and material in Indian condition. The effectiveness of the modifications was measured using consequence assessment. One of the major benefits of the modification is that chlorine release from the proposed storage facility can be managed with on-site Emergency Response Plan (ERP), thus excluding the need for off-site ERP.

Finally, an on-site emergency response plan was developed and implemented through an emergency on the basis of a hypothetical scenario of chlorine release from the storage facility. Network communication systems

for emergency response plan for chlorine release were prepared and presented. In order to test the effectiveness of the plan, a full scale mock drill was conducted.